

Metallic vs. Dielectric Modeling in WIPL-D

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Abstract: Simulations were run in WIPL-D [1] using homogeneous metallic or dielectric material separately with the same scattering structure at grazing angle. The frequency domain (FD) data was processed with Gaussian windowing and the inverse discrete Fourier transform. The resulting time domain (TD) plots are compared. The conclusion is that a metallic structure simulation can provide information relevant to the dielectric structure in much less time using fewer unknowns. An approximation for the structure's observed resonance is discussed.

Keywords: WIPL-D, scattering, simulation, resonance

1. Problem Statement and Diagram

A vertically polarized plane wave is incident on a structure 100 m from the source. The structure is a rectangular cylinder, centered at the origin and located above a perfect electric conductor (PEC) ground plane. The cylinder has dimensions: height 5.5 ft, breadth 1.5 ft, width 0.5 ft. The source is located 6 ft above the ground plane. The monostatic case with 1° angle of incidence is simulated to find the field scattered back toward the source by the structure. Figure 1 is a diagram of the problem statement.

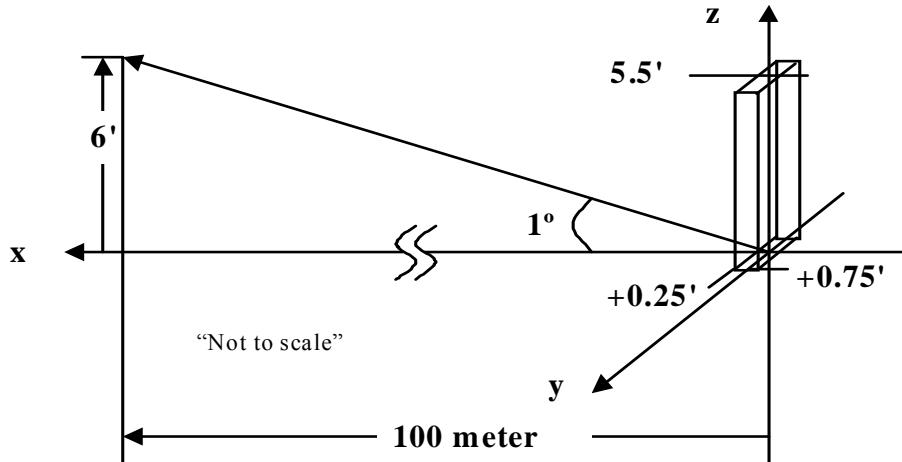


Figure 1: Problem Statement Diagram

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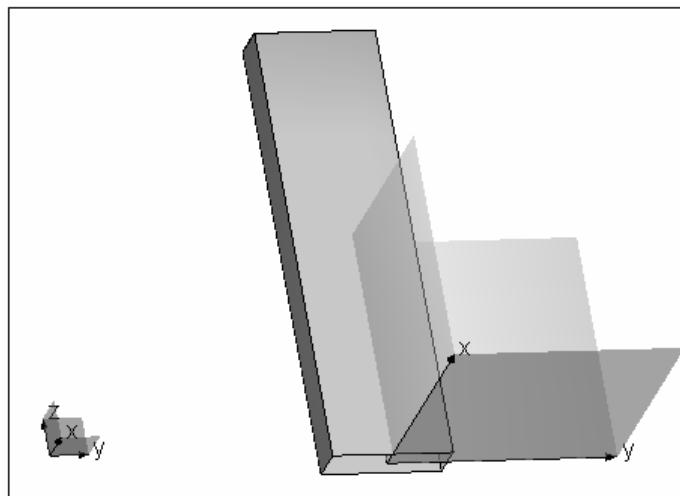


Figure 2: WIPL-D Model of Metallic Structure

2. Metallic Simulation Results

A model was constructed in WIPL-D for the metallic structure, shown above in Figure 2. The structure is closed on the top, but open on the bottom, since it is placed on an xy plane of PEC symmetry. The metallic material parameters are set as PEC (zeroth domain) by WIPL-D. The frequency range of interest is 5 MHz to 1 GHz with 200 data points simulated, giving a 5 MHz frequency step size. Figure 3 shows the FD data from the WIPL-D simulation.

The low frequency data show a resonance near 40 MHz. This resonance is discussed in Section 5. The frequency range above 500 MHz is smooth and continuous. Additional metallic simulations run with higher frequencies up to 2 GHz also showed continuous, smooth behavior.

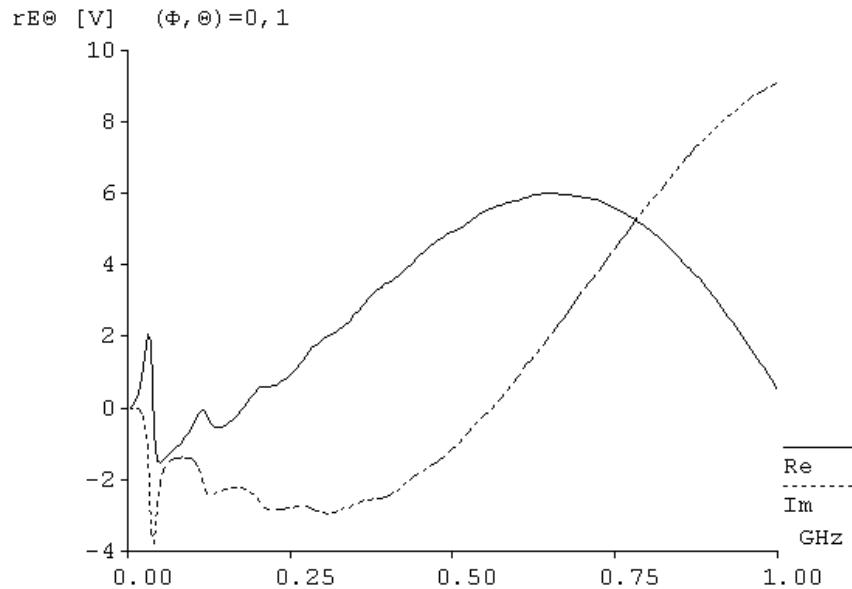


Figure 3: WIPL-D Metallic Data

3. Dielectric Simulation Results

The same structure model used for the metallic project was also used for the dielectric simulations, except that the material parameters were set for dielectric domain as follows: relative permittivity, $\epsilon_r = 81$, relative permeability, $\mu_r = 0$, and conductivity, $\sigma = 0.7 \text{ S/m}$. The same frequency range was also used. Figure 4 shows the dielectric data from WIPL-D.

As in the metallic case, the low frequency data show a resonance near 40 MHz, which is discussed in Section 5. Dielectric simulations with higher stop frequencies are being run to confirm continuous, smooth higher frequency data.

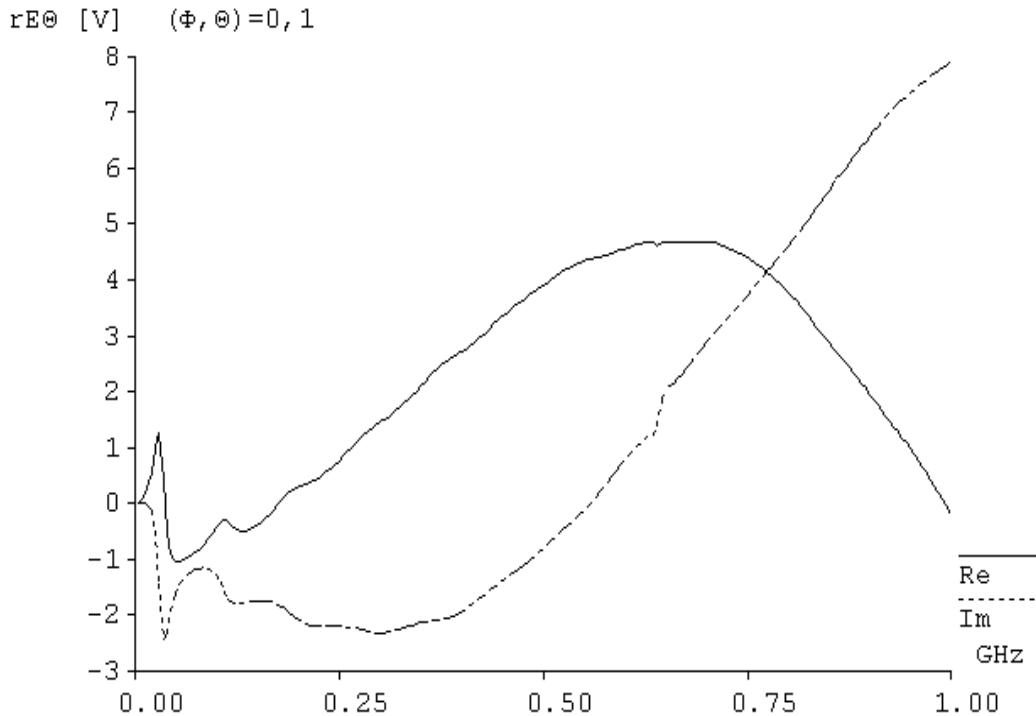


Figure 4: WIPL-D Dielectric Data

4. Signal Processing for Time Domain Response

The FD data from the WIPL-D simulations were processed using Gaussian windowing and the inverse discrete Fourier transform (ifft function), with $t = n\Delta T$ and $f = k\Delta f$. The length of the frequency vector is extended to $N = 2048$, padded with zeros and the conjugate symmetry is inserted. The frequency resolution $\Delta f = 5 \text{ MHz}$ gives a frequency range $F = 10.24 \text{ GHz}$ before windowing, and a TD record length $T_0 = 200 \text{ ns}$. The time sampling interval $\Delta T = 97.6 \text{ ps}$.

A Gaussian window function $g(t)$ defined below is shown in Figure 5, with $\alpha = 4 \text{ ns}$ (width) and $\tau = 4 \text{ ns}$ (delay).

$$g(t) = e^{-\Psi^2}; \Psi = \frac{4}{\alpha}(t - \tau)$$

Using the discrete Fourier transform (fft function), $g(t)$ is transformed into FD, $G(f)$ shown in Figure 6.

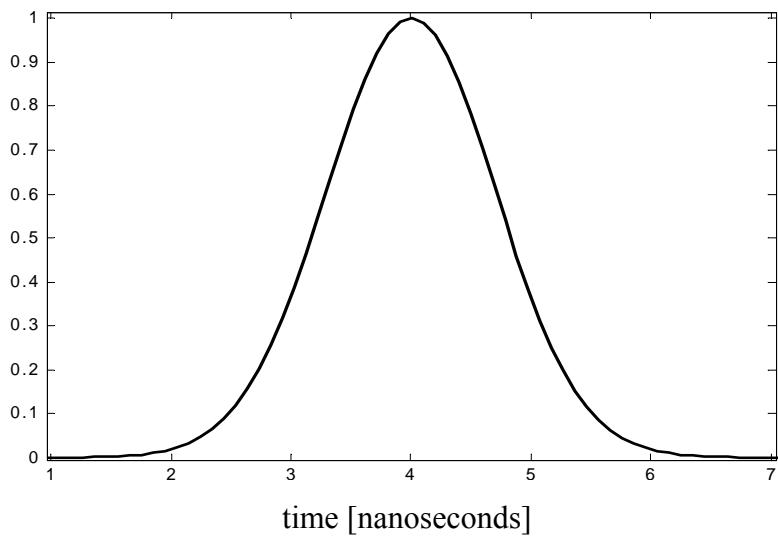


Figure 5: Gaussian Window, $g(t)$

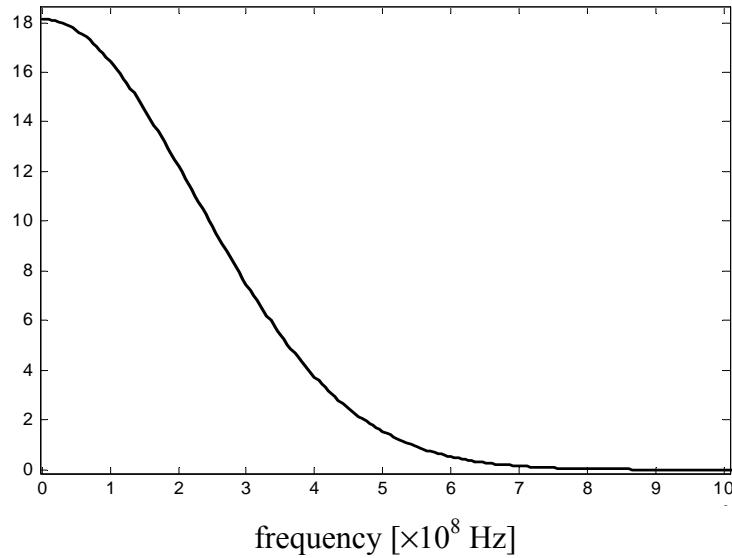


Figure 6: Gaussian Window, $G(f)$

The FD data vector is multiplied by $G(f)$, which is equivalent to convolution in TD. The windowed FD data is then transformed to the TD using the inverse discrete Fourier transform (ifft function). The resulting TD responses for the metallic and dielectric cases are plotted together in Figure 7.

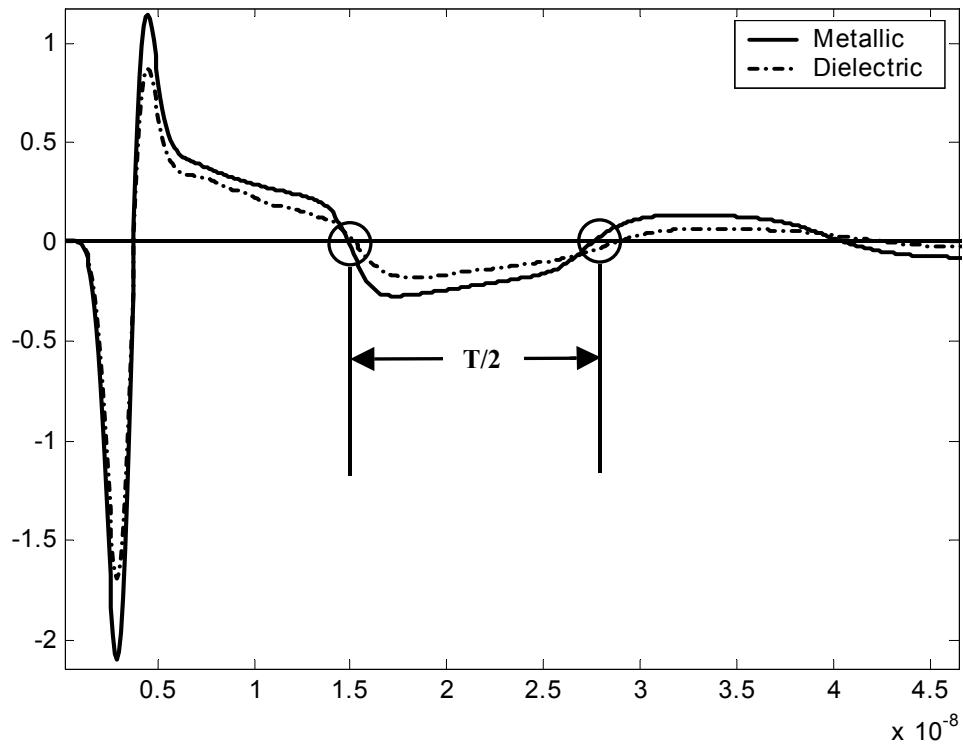


Figure 7: TD Responses for Metallic and Dielectric Simulations

5. Discussion

The scattering from the metallic structure clearly has greater magnitude than the dielectric, but we observe that the shape and zero crossings are approximately the same. The first two zero crossings after the initial pulse, which are circled on Figure 7 above, will be used to estimate the resonance of each of the two cases. From the WIPL-D data (magnitude), Figure 8 zooms in on the low frequency resonance peaks in the metallic and dielectric data, which occur in the 30 MHz to 40 MHz range.

This resonance will be approximated from the TD response by calculating the half-period $T/2$, indicated on Figure 7, as the difference between the first and second zero crossing after the initial pulse. For the metallic case, this gives $T/2 = 12.6$ ns, and a frequency $f_r = 1/T = 39.7$ MHz. For the dielectric case, this gives $T/2 = 13.5$ ns and a frequency $f_r = 1/T = 37$ MHz. At 5 MHz resolution, the exact frequency is not discernible. The estimates agree within the range observed in Figure 8.

Table 1 below summarizes the information from the graph and the calculations.

TD Response	zero crossings		zc2-zc1	Period	Resonance
	zc1 [ns]	zc2 [ns]	[ns]	T [ns]	$f_r = 1/T$
Metallic	14.9	27.5	12.6	25.2	39.7 MHz
Dielectric	15.2	28.7	13.5	27	37.0 MHz

Table 1: Resonance from TD data

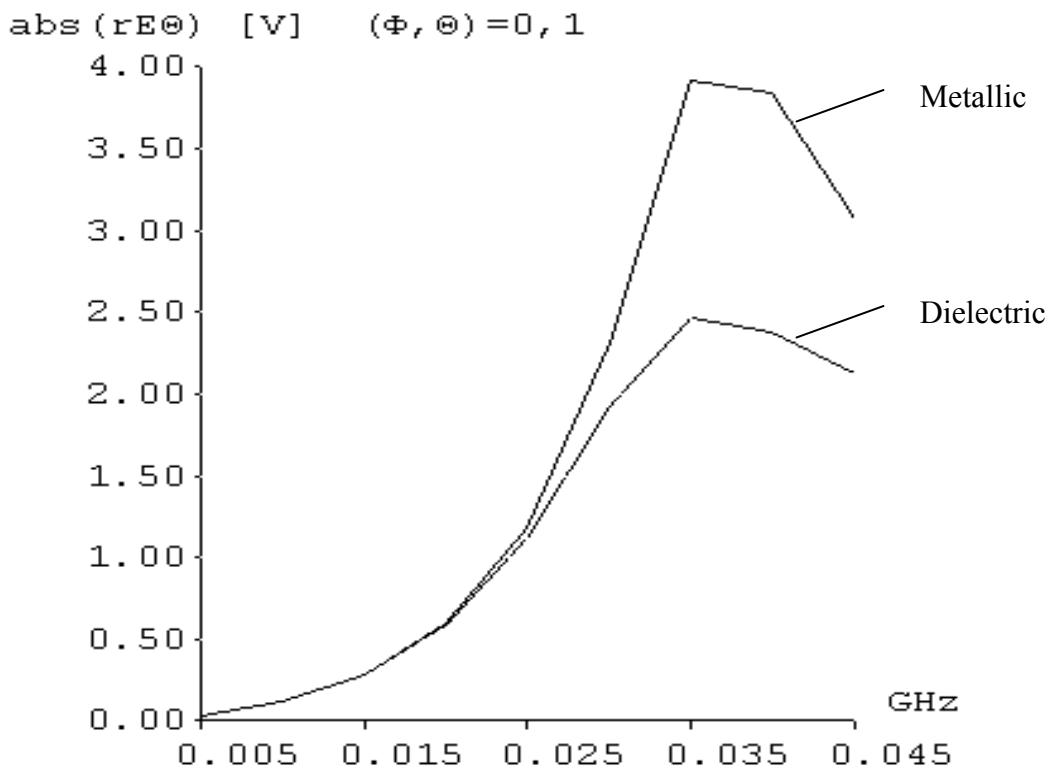


Figure 8: Resonance in WIPL-D Data, Magnitude

6. Conclusion

This investigation has shown that relevant information regarding the resonance of a dielectric structure can be approximated from WIPL-D simulation of the same structure as metallic. A metallic simulation can be completed and analyzed in less time because it requires half or less the number of unknowns necessary for a dielectric simulation. The dielectric structure in this paper required 1872 unknowns, compared to 801 unknowns for the metallic. The computer used for both WIPL-D simulations was a DELL Precision 420 Workstation, P3 x 2 CPU, 733 MHz with 1 GB RAM. The metallic simulation took less than 2 hours, while the dielectric simulation took more than 16 hours. Ongoing simulations with higher stop frequencies indicate that this difference in computational time grows larger as the simulation stop frequency is raised.

References

- [1] B. M. Kolundžija, J. S. Ognjanović, T. K. Sarkar, "WIPL-D Electromagnetic Modeling of Composite Metallic and Dielectric Structures, Software and User's Manual", Artech House, 2000.
- [2] R. D. Strum, D. E. Kirk, "First Principles of Discrete Systems and Digital Signal Processing", Addison-Wesley, 1989.